Defense Technical Information Center Compilation Part Notice

ADP010728

TITLE: Transonic Simple Straked Delta Wing

DISTRIBUTION: Approved for public release, distribution unlimited

This paper is part of the following report:

TITLE: Verification and Validation Data for Computational Unsteady Aerodynamics [Donnees de verification et de valadation pour l'aerodynamique instationnaire numerique]

To order the complete compilation report, use: ADA390566

The component part is provided here to allow users access to individually authored sections of proceedings, annals, symposia, ect. However, the component should be considered within the context of the overall compilation report and not as a stand-alone technical report.

The following component part numbers comprise the compilation report:
ADP010704 thru ADP010735

19E. TRANSONIC SIMPLE STRAKED DELTA WING

Evert G.M. Geurts
National Aerospace Laboratory NLR, The Netherlands

INTRODUCTION

The unsteady transonic flow during manoeuvres of fighters is not very well understood. For instance, large time delays and severe dynamic overshoots in normal force may occur, which cannot be predicted accurately by numerical methods. As a consequence, to be conservative structures must be over-designed or flight envelopes must be unnecessarily restricted. Therefore, a better understanding of the unsteady transonic flows, which occur during manoeuvres, is of interest for the development and operation of fighters.

This data set relates to an unsteady transonic wind tunnel test, on a highly instrumented semi-span simple straked delta wing model. Harmonic pitch as well as manoeuvre simulations were performed.
The objectives of the test were:

- To develop a better understanding of the physics of the unsteady vortex flow about a simple straked delta wing,
- The generation of a steady and unsteady airloads database for the use in the validation of CFD codes.

A first selection of test data for the validation of unsteady CFD codes related to this test is given in the following table and is motivated below. For harmonic oscillation the selected data points were chosen to highlight:

- Vortex flow breakdown
- Onset to Shock-Induced Trailing Edge Separation (SITES) and leading edge separation at transonic speeds.

Harmonic oscillation				
Mach	incidence	amplitude	frequency	data point
0.225	22.0	8.0	5.7	151
0.600	22.0	8.0	5.7	375
0.600	10.0	4.0	5.7	358
0.900	6.0	4.0	5.7	566
0.900	22.0	8.0	5.7	580
0.900	10.0	4.0	7.6	593
0.900	10.0	8.0	7.6	602
0.900	22.0	8.0	7.6	605

The y=0 plane was located on a distance of 7 mm from the tunnel sidewall which corresponded to the local displacement thickness of the tunnel sidewall boundary layer. To impose the start of the vortex on the apex to avoid interference of vortex with sidewall boundary layer, a little flat plate, the filler plate was attached to the model apex. As starting point for transonic calculation data point 566 was chosen, where conditions are stable. As primary point of interest the effect of Mach number is covered by the selection of data points 151, 375 and 580. At M = 0.225, data point 151 shows the effect of the model oscillating between 14° and 30° incidence at 5.7 Hz. With vortex bursting starting at about 22°, this oscillation provides a maximum pitch rate at the burst point. Similar data are given for M = 0.6 in data point 375 where vortex breakdown apparently begins between 23° and 24° and for M=0.9 in data point 580. Data point 605 was chosen at M = 0.9 and at the higher frequency of 7.6 Hz to provide an approximately constant reduced frequency when compared with data point 375 at M = 0.6. In the case of data point 605, vortex bursting begins at about 18° incidence.

The onset to SITES and leading edge separation at M = 0.9 occurs at an incidence between 10° and 12°. Data point 593 was chosen to show these effects. In order to highlight these transonic transitions, data point 358 was chosen to show how aerodynamics responded to oscillations of 4° amplitude at 10° mean angle and M = 0.6, where no such transitions occur. Frequency for the M = 0.6 case was 5.7 Hz and for the M = 0.9 case 7.6 Hz in order to maintain an approximately constant reduced frequency. Data point 580 was added to show frequency effects when compered with data point 605; data point 602 shows amplitude effects when compared with data point 593. Data are presented as the first seven harmonics of the pressures, balance data and accelerations.

Manoeuvres				
Mach	incidence	amplitude	frequency	data point
0.225	22.0	16.0	3.8	306
0.600	22.0	16.0	3.8	480
0.900	22.0	16.0	3.8	656

To cover the manoeuvring part of the test the large amplitude motions of 16° amplitude centred on a mean angle of 22°, were chosen to provide a dynamic variation of flow fields covering attached, vortex, burst vortex and developing separated flows for incidences from 7° to 37°. The three Mach numbers are represented by data points 306 (M=0.225), 480 (M=0.60) and 656 (M=0.90). In all cases the frequency was held constant at 3.8 Hz in order to simulate the same manoeuvre at different speeds.

Since these data points are for transient and not for oscillatory motions, they are represented in a time history format and thus do not have the harmonic part that is used in the selected data points for harmonic oscillations.

LIST OF SYMBOLS AND DEFINITIONS

Definitions

Figure 1 shows an example of a presentation from the geometry file (CATIA) included in the database and the origin of the body fixed axis system.

x-axis In the Wing Reference Plane following the root chord line of the basic wing panel[1] at a distance of 62.3 mm (see figure 2). The root chord line of the basic wing panel and the line connecting the 0 % chord points (Leading Edge) define the Wing Reference Plane (WRP).

y-axis In the Wing Reference Plane, perpendicular to the x axis, going through 48.24 % of the root chord line of the basic wing panel (= 73.27 % of the root chord line of the strake). The y-axis coincides with the rotation axis or pitching axis of the experiment.

z-axis Perpendicular to x-axis and y-axis. The z = 0 plane is the Wing Reference Plane. Both the root chord line of the strake, the rotation axis and the line connecting the 0 % chord points are in this plane.

The Trailing Edge is one straight line. Due to the twist, this line is crossing the Wing Reference Plane at the root chord of the basic wing panel. Although the apex of the strake is in the Wing Reference Plane, the chord line of the y = 0 section is not precisely in the Wing Reference Plane; it has a 0.0803° more positive angle of attack than the root chord line of the basic wing panel.

Non-dimensionalisation

Mean (NOT steady)

suffix 0 indicates the zero-th harmonic component

Unsteady

all unsteady signals have been decomposed into harmonic components

the harmonic component is indicated by suffix h,

- each harmonic component has been decomposed into
- a real (in-phase) and an imaginary (out-of-phase) part, e.g. Cp h = Re (Cp h) + i * Im (Cp h)

Pressures

Mean		Unsteady	
Cp 0	= (p 0 - ps) / q	Cp h	= (p h) / q * dalpha

Balance loads

Mean		Unsteady	
CN 0	= Normal Force / (q * Sref)	CN h	= Normal Force / (q * Sref * dalpha)
Cm 0	= Pitching Moment / (q * Sref * cref)	Cm h	= Pitching Moment / (q * Sref * cref * dalpha)
Cl 0	= Rolling Moment / (q * Sref * bref)	Cl h	= Rolling Moment / (q * Sref * bref * dalpha)

Chordwise sectional loads

$$\text{CN\_u 0} = -\int_0^1 (Cp^+\ 0)\ d(x/c) \qquad \text{CN\_u h} = -\int_0^1 (Cp^+\ h)\ d(x/c)$$

$$\text{CN\_l 0} = +\int_0^1 (Cp^-\ 0)\ d(x/c) \qquad \text{CN\_l h} = +\int_0^1 (Cp^-\ h)\ d(x/c)$$

$$\text{CN\_t 0} = +\int_0^1 (Cp^-\ 0 - Cp^+\ 0)\ d(x/c) \qquad \text{CN\_t h} = +\int_0^1 (Cp^-\ h - Cp^+\ h)\ d(x/c)$$

[1] Since a common outboard wing was part of two different wind tunnel models, this common part was defined as the basic wing panel. For this test integration with a simple strake was realised.

$$\text{Cm\_u 0} = -\int_0^1 (Cp^+ 0)(x/c-0.25)\, d(x/c)$$

$$\text{Cm\_l 0} = +\int_0^1 (Cp^- 0)(x/c-0.25)\, d(x/c)$$

$$\text{Cm\_t 0} = +\int_0^1 (Cp^- 0 - Cp^+ 0)(x/c-0.25)\, d(x/c)$$

$$\text{Cm\_u h} = -\int_0^1 (Cp^+ h)(x/c-0.25)\, d(x/c)$$

$$\text{Cm\_l h} = +\int_0^1 (Cp^- h)(x/c-0.25)\, d(x/c)$$

$$\text{Cm\_t h} = +\int_0^1 (Cp^- h - Cp^+ h)(x/c-0.25)\, d(x/c)$$

Spanwise sectional loads

$$\text{CN\_u 0} = -\int_0^1 (Cp^+ 0)\, d(y/b)$$

$$\text{Cl\_u 0} = -\int_0^1 (Cp^+ 0)(y/b)\, d(y/b)$$

$$\text{CN\_u h} = -\int_0^1 (Cp^+ h)\, d(y/b)$$

$$\text{Cl\_u h} = -\int_0^1 (Cp^+ h)(y/b)\, d(y/b)$$

Notes:

- All harmonic (h>0) components have been non-dimensionalised by the first harmonic of dalpha (in radians).
- For layout reasons, the 0 indicating the zero-th harmonic component (mean value) is sometimes omitted.
- Pitching moment: - Wing: about the rotation axis
  - Sections: about 25 % local chord
- Coefficients of spanwise sections: integration from y=0 to tip; rolling moment about y=0.
- The section number of the section coefficients is either indicated at the left hand side of the presented values (e.g. see table 3) or an additional suffix is used according to the following convention:

C1_2_3 h:	1_	2_	3_	h
	N: normal force	u: upper	section number	harmonic number
	M: pitching moment	l: lower		
	l: rolling moment	t: total		

- Chordwise sectional load integration: Between leading edge and first pressure transducer the static pressure and the unsteady pressure were assumed to be constant and equal to the values of the first pressure transducer. At the trailing edge the static pressure coefficient was assumed to be zero. Between the trailing edge and the last pressure transducer the unsteady pressure was assumed to be constant and equal to the values of the last pressure transducer.
- Spanwise sectional load integration: Between the symmetry plane and the first pressure transducer the steady pressure and the unsteady pressure were assumed to be constant and equal to the values of the first pressure transducer. At the tip the static pressure was assumed to be zero. Between the tip and the last pressure transducer the unsteady pressure was assumed to be constant and equal to the values of the last pressure transducer.
- The result of the pressure integration was NOT multiplied by $1/\pi$ or $2/\pi$.

Symbols and definitions

acc	(m/s^2)	acceleration (acc_11 is acceleration measured by accelerometer 11: see table 3)
alpha, α	(°)	incidence relative to x-axis as determined from LVDT signal
		(Note that incidence relative to root chord is alpha + 0.0803°)
		harmonic oscillations: zero-th harmonic component of the signal
		manoeuvres: half the sum of maximum and minimum of (1-cos) input
b	(m)	(local) span: measured from strake root chord (y = 0)

bref	(m)	reference span used in non-dimensionalising rolling moment: (distance between y=0 and tip section, excluding wing tip fairing): bref = 0.417900 (m)
c	(m, mm)	(local) chord
Cl	(-)	rolling moment coefficient
Cm	(-)	pitching moment coefficient
CN	(-)	normal force coefficient
Cp	(-)	pressure coefficient
cr, cref	(m, mm)	length of reference chord: root chord (at y = 0): cref = 0.820700 (m)
dalpha, dα	(°, rad)	model amplitude as determined from LVDT signal harmonic oscillations: first harmonic component manoeuvres: half of top-top value of (1-cos) input
DPN, dpn		data point number
freq, f	(Hz)	frequency, frequency of model oscillation
harm, h		harmonic component: harm = 1 refers to the excitation frequency of the model
i		$\sqrt{-1}$
Im		Imaginary part, e.g. CN h= Re (CN h) + i * Im (CN h)
k	(-)	reduced frequency, k = π * f * cref / V
LVDT		Linear Variable Differential Transducer, refers to displacement transducer mounted between a fixture on the turntable and a crank on the main axis
M, Mach	(-)	freestream Mach number
P, p	(Pa)	pressure
p.a.		pitching axis, rotation axis (see figure 2)
p_d	(°)	pitch deflection of main balance (> 0 nose up)
PHARAO		Processor for Harmonic And RAndom Oscillations
ps	(Pa)	freestream static pressure
q, Q	(Pa)	freestream dynamic pressure
r_d	(°)	roll deflection of main balance (>0 port-side down)
Re	(-)	Reynolds number, Re = V * cref / ν
Re		Real part, e.g. CN h= Re (CN h) + i * Im (CN h)
SiS		Simple Strake
SITES		Shock-Induced Trailing Edge Separation
Sref	(m^2)	wing reference area: wing area, including strake, Sref = 0.144406 (m^2)
T	(s)	duration of a full (1-cos) input, T= 1/3.8
T	(K)	Temperature
V	(m/s)	Freestream velocity
WRP		Wing Reference Plane (see Definitions)
x	(mm)	ordinate (see Definitions)
x/c	(-, %)	relative chordwise position
y	(mm)	spanwise ordinate (see Definitions)
y/b	(-, %)	relative spanwise position
z	(mm)	ordinate (see Definitions)

Greek

α	(°)	incidence relative to x-axis as determined from LVDT signal (Note that incidence relative to root chord is alpha + 0.0803°) harmonic oscillations: zero-th harmonic component of the signal manoeuvres: half the sum of maximum and minimum of (1-cos) input

$d\alpha$, dalpha	(°, rad)	model amplitude as determined from LVDT signal
		harmonic oscillations: first harmonic component
		manoeuvres: half of top-top value of (1-cos) input
ν	(m^2/s)	(freestream) kinematic viscosity

Superscripts and postscripts

+	upper
-	lower
h	harmonic; when no harmonic is indicated the mean value is presented
i	instationary
tot	total
_in	inertia part
_l	lower
_m	mean (zero-th harmonic)
_u	upper
_t	total
0	(zero-th harmonic) mean: when no harmonic is indicated the mean value is presented

FORMULARY

1 General Description of model

1.1	Designation	Transonic Simple Straked Delta Wing
1.2	Type	Half model
1.3	Derivation	Outboard wing: Modified NACA 64A204, linearly lofted between root and tip Strake: diamond shaped with sharp leading edge
1.4	Additional remarks	Filler plate attached to model apex (remark in introduction)
1.5	References	Refs. 1, 2, 3, 7

2 Model Geometry

2.1	Planform	Trapezoidal outboard wing with simple strake (see figure 2)
2.2	Aspect ratio	2.4187
2.3	Leading edge sweep	Wing: 40°, Strake: 76°
2.4	Trailing edge sweep	No
2.5	Taper ratio	-
2.6	Twist	-3.0°, the y = -62.3 section has 0.0° incidence with respect to WRP, the y = -417.9 section (tip) has –3.0° incidence; the panel is linearly lofted between root and tip. Twist is applied by rotation about the leading edge
2.7	Root chord	0.8207 m
2.8	Semi-span of model	0.4179 m
2.9	Area of planform	0.144406 m^2
2.10	Leading-edge flap	Present, but not deflected
2.11	Trailing-edge flap	Present, but not deflected
2.12	Reference locations and profile definitions	See CATIA geometry file
2.13	Form of wing-body or wing-root junction	Area between outboard wing and strake smoothed
2.14	Form of wing tip	Tip fairing present (geometry included in CATIA file in database)
2.15	Additional remarks	Planform identical to (half of) full-span model of Low Speed

	Straked Delta Wing (case 18.E)
	Geometry included as CATIA file in database
2.16 References	Refs. 2, 3, 7

3 Wind Tunnel

3.1 Designation	NLR High Speed Tunnel (HST)
3.2 Type of tunnel	Continuous, variable pressure
3.3 Test section dimensions	Height: 1.6 m, width: 2.0 m, enclosed in large plenum chamber
3.4 Type of roof and floor	Slotted, 6 slots per wall
3.5 Type of side walls	Solid
3.6 Ventilation geometry	Roof and floor: open ratio 12%
3.7 Displacement thickness of side wall boundary layer	~ 7 mm.
3.8 Thickness of boundary layers at roof and floor	-
3.9 Method of measuring Mach number	Derived from settling chamber stagnation pressure and plenum chamber static pressure
3.10 Flow angularity	< 0.1° in centre of test section, < 0.25° elsewhere
3.11 Uniformity of Mach number over test section	< 0.4% in $\Delta M/M$ at supersonic Mach numbers
3.12 Sources and levels of noise or turbulence in empty tunnel	< 1% in rms p/q for M=0.8
3.13 Tunnel resonance	No evidence of resonance in present test
3.14 Additional remarks	Information on flow angularity and Mach number uniformity available only along test section centre line
3.15 References on tunnel	Ref. 8

4 Model motion

4.1 General description	Sinusoidal pitching and manoeuvre simulations (half/full [1-cosine], half/full cosine inputs). Pitching axis location at 73.27 % root chord
4.2 Reference co-ordinate and definition of motion	Oscillation amplitude measured with LVDT on actuator
4.3 Range of amplitude	0.5°, 2°, 4°, 8° and 16°
4.4 Range of frequency	3.8, 5.7, 7.6, 11.4 and 15.2 Hz
4.5 Method of applying motion	Electro-hydraulic shaker system (HYDRA), Ref. 9
4.6 Timewise purity of motion	Adequate purity of sinusoid
4.7 Natural frequencies and normal modes of model and support system	Lowest: 91.2 Hz (balance torsion combined with model pitching) Further: 136.6 Hz and 166.5 Hz and higher
4.8 Actual mode of applied motion including any elastic deformation	Measured with 15 accelerometers (12 wing, 3 strake) Position and output included in database files. The angular deflections, calculated from the total balance loads and stiffness matrices are presented in the database files.
4.9 Additional remarks	Rotation axis location at same position as in Low Speed Straked Delta Wing Test

5 Test Conditions

5.1 Model planform area/tunnel area	0.0451
5.2 Model span/tunnel height	0.2090
5.3 Blockage	Estimated 3 % of dynamic pressure: no blockage or upwash corrections applied due to scarce information at extreme conditions

5.4	Position of model in tunnel	Standard sidewall mounting
5.5	Range of Mach number	0.225, 0.6 and 0.9
5.6	Range of tunnel total pressure (Reynolds number)	Re ≈ 3.8×10^6 for M=0.225, Re ≈ 8.0×10^6 for M=0.225, 0.6 and 0.9 Re ≈ 14.0×10^6 for M=0.9
5.7	Range of tunnel total temperature	Actual total temperature value included in database files
5.8	Range of model steady or mean incidence	4° to 48° (adjusted values)
5.9	Definition of model incidence	Relative to WRP (see Definitions)
5.10	Position of transition, if free	-
5.11	Position and type of trip, if transition fixed	Strips of 2mm width on upper and lower side of outboard wing (y < -108.65 mm), starting 14.5 mm downstream of leading edge, measured perpendicular to the leading edge. Grit size: 88 μm (Carborundum 150)
5.12	Flow instabilities during tests	None encountered
5.13	Changes to mean shape of model due to steady aerodynamic load	Not measured
5.14	Additional remarks	In test programme and introduction nominal adjusted values are indicated; correct geometric values are in the database files
5.15	References describing tests	Ref. 7

6 Measurements and Observations

6.1	Steady pressures for the mean conditions		Yes
6.2	Steady pressures for small changes from the mean conditions		No
6.3	Quasi-steady pressures (6 Hz)		Yes
6.4	Unsteady pressures	• Harmonic components	Yes
		• Time histories	Yes
6.5	Steady loads for the mean conditions	• Measured directly (total)	Yes
		• Integrated sectional pressures (see Definitions)	Yes
6.6	Steady loads for small changes from the mean conditions		No
6.7	Quasi-steady loads (6 Hz)	• Measured directly (total)	Yes
		• Integrated sectional pressures (see Definitions)	Yes
6.8	Unsteady loads	• Measured directly (total)	Yes
		• Integrated sectional pressures (see Definitions)	Yes
6.9	Measurement of actual motion at points on model		Yes
6.10	Observation or measurement of boundary layer properties		No
6.11	Visualisation of flow (demonstration)		Yes
6.12	Visualisation of shock wave movements		No
6.13	Additional remarks	Demonstration during this test resulted in a flow visualization test in August 1996 (Refs. 16, 19, 20, 21, 22)	

7 Instrumentation

7.1 Steady pressure

7.1.1	Position of orifices spanwise and chordwise	See figure 2 and table 3
7.1.2	Type of measuring system	95 in situ pressure transducers, DC part of time signal measured in

	conditioning units
7.2 Unsteady pressure	
7.2.1 Position of orifices spanwise and chordwise	See figure 2 and table 3
7.2.2 Diameter of orifices	0.8 mm
7.2.3 Type of measuring system	AC part of time signals measured by PHARAO (Ref. 14)
7.2.4 Type of transducers	Endevco: 8514-10, 8507B-15, 8507-5M, Kulite: XCS 093-5D
7.2.5 Principle and accuracy of calibration	Calibration of data acquisition system before test
7.3 Model motion	
7.3.1 Method of measuring motion	LVDT: Sangamo AFG 5.0 S
7.3.2 Method of determining spatial mode of motion	15 accelerometers (12 in wing, 3 in strake) Endevco: 2222B/2222C, Kulite: GY-155-100/250
7.3.3 Accuracy	better than 0.015 mm
7.4 Processing of unsteady measurements	
7.4.1 Method of acquiring and processing measurements	Application of Phase Locked Time Domain Averaging on time traces and processed to first seven harmonics
7.4.2 Type of analysis	Harmonic components (0 to 7) and time histories
7.4.3 Unsteady pressure quantities obtained and accuracy's achieved	Harmonic components and time histories, for accuracy see 9.1.6; application of sensor characteristics, correction for zero measurements applied
7.4.4 Method of integration to obtain forces	Trapezoidal rule with specials at leading and trailing edge
7.5 Additional remarks	Positions of instrumentation included in output files (see table 3)
7.6 References on techniques	Refs. 4, 5, 14

8 Data presentation

8.1 Test cases for which data could be made available	See tables 1 and 2
8.2 Test cases for which data are included in this document	Summarized and motivated in Introduction
8.3 Steady pressures	Mean values; example in table 3 (see Database)
8.4 Quasi-steady or steady perturbation pressures	Example in table 3 and table 4 (see Database)
8.5 Unsteady pressures	Harmonic measurements: first seven harmonics Manoeuvres: time data Examples in table 3 and table 4 (see Database)
8.6 Steady forces or moments	Example in table 3 (see Database)
8.7 Quasi-steady or unsteady perturbation forces	
8.8 Unsteady forces and moments	Harmonic measurements: first seven harmonics Manoeuvres: time data examples in table 3 and table 4 (see Database)
8.9 Other forms in which data could be made available	Harmonic measurements: time traces
8.10 Reference giving other representations of data	Refs. 10, 11, 12, 13, 16

9 Comments on data

9.1 Accuracy	
9.1.1 Mach number	+/- 0.001
9.1.2a Steady incidence turntable	+/- 0.002 + 0.0004 * alpha° [°]
9.1.2b Steady incidence shaft	+/- 0.005°

	9.1.3 Pitch amplitude	+/- 0.005°
	9.1.4 Pitch amplitude	+/- 0.0005
	9.1.5 Steady pressure derivatives	+/- 0.3 per cent
	9.1.6 Unsteady pressure coefficients	+/- 0.5 per cent
9.2	Sensitivity to small changes of parameter	-
9.3	Non-linearity's	-
9.4	Influence of tunnel total pressure	Unsteady measurements had short acquisition times and the total pressure can be assumed constant over each measurement.
9.5	Wall interference corrections	Not applied
9.6	Other relevant tests on same model	Refs. 16, 19 (UTDP VISU test)
9.7	Relevant tests on other models of nominally the same shapes	Ref. 6 (UTDP LCO test), Ref. 16 (UTDP VISU test), Ref. 17 (NLR Subsonic Straked Delta Wing Test)
9.8	Any remarks relevant to comparison between experiment and theory	LCO prediction method mentioned in Ref. 6
9.9	Additional remarks	Structure of file set-up included in README file in database; example of data output indicated in table 3.
9.10	References on discussion of data	Refs. 6, 7, 10, 11, 12, 13, 18

10 Personal contact for further information

Evert G.M. Geurts
Department of Aerodynamic Engineering and Aeroelasticity
Phone: +31 20 5113455
Fax: +31 20 5113210
Email: geurts@nlr.nl

National Aerospace Laboratory NLR

Anthony Fokkerweg 2	P.O. Box 90502
NL 1059 CM Amsterdam	NL 1006 BM Amsterdam
The Netherlands	The Netherlands

Phone: +31 20 5113113
Fax: +31 20 5113210
Website: http://www.nlr.nl

11 List of references

1 Geurts, E.G.M., den Boer, R.G., (in Dutch) "Eerste uitwerking van voorstel instationaire transsone deltavleugel proeven in HST", NLR Memorandum AE-87-001 U, 1987.

2 Sijtsma, H.A., "Computational assessment of a lower wing surface modification of an F-16A aeroelastic windtunnel model", NLR TR 88143 L, 1988.

3 den Boer, R.G., "Report of the design of two semi-span wind tunnel models with corresponding support system, to be used for unsteady tests in the High Speed Tunnel (HST) of the National Aerospace Laboratory (NLR) in the Netherlands", NLR TR 89057 L, 1989.

4 Geurts, E.G.M., "Experiments with a trial strain gage balance", NLR Memorandum AE-88-005 U, 1988.

5 Geurts, E.G.M., "Continued dynamic experiments with a trial strain gage balance", NLR TR 89052 L, 1988.

6 Cunningham, Jr., A.M., den Boer, R.G., Dogger, C.S.G., Geurts, E.G.M., Retel, A.P., Zwaan, R.J., "Unsteady transonic wind tunnel tests on a 1:9 scaled semi-span model of an F-16 with outboard wing oscillating in pitch and a semi-span straked delta wing model, oscillating in pitch", NLR CR 93386 U (Parts I to IV), 1993.

Part I: Objectives, model, test setup, data acquisition and processing techniques, test program, presentation format

Part II: Selected results of the test on the 1:9 scaled F16 model oscillating in pitch

Part III: Selected results of the test on the semi-span straked delta wing model oscillating in pitch

Part IV: Selected results of the test on the semi-span straked delta wing model simulating pitch manoeuvres

7 Cunningham, Jr., A.M., den Boer, R.G., Dogger, C.S.G., Geurts, E.G.M., Retel, A.P., Zwaan, R.J., "Unsteady transonic wind tunnel test on a semi-span straked delta wing model, oscillating in pitch", NLR CR 93570 L (Parts I to III), 1993

Part I : Description of Model, Test Setup, Data Acquisition and Data Processing, also published as WL-TR-94-3094

Part II: Selected Data Points for Harmonic Oscillation also published as WL-TR-94-3095

Part III:Selected Data Points for Simulated Manoeuvres, also published as WL-TR-94-3096.

8 NN., "Users guide to the High Speed Tunnel (HST): edition 1977".

9 Poestkoke, R., "Hydraulic test rig for oscillating wind-tunnel models", NLR MP 76020 U, 1976.

10 Boer, R.G. den, Cunningham Jr., A.M., "Unsteady Transonic Wind Tunnel Testing of Fighter Type Wings", 31st AIAA / ASME / ASCE / AHS / ASC Structures, Structural Dynamics and Materials Conference, Long Beach, California, 2-4 April 1990.

11 Cunningham Jr., A.M., Boer, R.G. den, "Transonic Wind Tunnel Investigation of Limit Cycle Oscillations on Fighter Type Wings", AGARD SMP Conference Proceedings 507: Transonic Unsteady Aerodynamics and Aeroelasticity, San Diego, California, 7-11 October 1991.

12 Cunningham Jr., A.M., Boer, R.G. den, "Transonic Wind Tunnel Investigation of Limit Cycle Oscillations on Fighter Type Wings - UPDATE", 33rd AIAA / ASME / ASCE / AHS / ASC Structures, Structural Dynamics and Materials Conference, Dallas, Texas, April 13-17, 1992.

13 Geurts, E.G.M., den Boer, R.G., Cunningham, Jr., A.M., "Unsteady Transonic Wind Tunnel Test of a Pitching Straked Wing at High Incidences", 33rd AIAA / ASME / ASCE / AHS / ASC Structures, Structural Dynamics and Materials Conference, Dallas, Texas, April 13-17, 1992 (also NLR MP 92155 L, 1992).

14 den Boer, R.G., "Application of the New NLR Measurement System PHARAO in Unsteady Wind Tunnel Tests on Straked Delta Wings", 18th ICAS Congress, Beijing, China, September 21-25, 1992 (also NLR TP 92441 U, 1992).

15 Geurts, E.G.M., "Presentation and Analysis of Results of an Unsteady Transonic Wind Tunnel Test on a Semi-Span Delta Wing Model, Oscillating in Pitch", International Forum on Aeroelasticity and Structural Dynamics, Manchester, United Kingdom, 26-28 June 1995 (also NLR TP 95523 U, 1995).

16 Geurts, E.G.M., "Flow Visualization and Particle Image Velocimetry on a Semi-Span Straked Delta Wing, Stationary and Oscillating in Pitch", European Forum on Wind Tunnels and Wind Tunnel Test Techniques – Proceedings P.48.1-P.48.11, Cambridge, United Kingdom, 14-16 April 1997.

17 Cunningham, Jr., A.M., den Boer, R.G., et.al., "Unsteady low speed wind tunnel test of a straked delta wing, oscillating in pitch", NLR TR 87146 L Parts I to VI, (also "published" in April 1988 as AFWAL-TR-8-3098, Parts I-VI).

Part I: General description and discussion of results

Part II: Plots of steady and zeroth and first order harmonic unsteady pressure distributions

Part III: Plots of zeroth and first order harmonic unsteady pressure distributions (concluded) and plots of steady and zeroth and first order harmonic overall loads

Part IV:Plots of time histories of pressures and overall loads

Part V: Plots of the overall loads spectra and the response of overall loads to single step (1-cos) inputs

Part VI: Presentation of the visualization program.

18 Cunningham, Jr, A.M., den Boer, R.G. , "Overview of Unsteady Transonic Wind Tunnel Test on a Semi-span Straked Delta Wing Oscillating in Pitch", WL-TR-94-3017, 1994.

19 Cunningham, Jr., Geurts, E.G.M., Dogger, C.S.G., Persoon, A.J., "Transonic Wind Tunnel Test on the Flow-Visualization of a Semi-Span Simple Straked Delta Wing Model', NLR CR 97577 L (Parts I to II), 1997.

Part 1: General Description

Part II: Presentation of (Selected) Test Results

20 Cunningham, Jr., Atlee M., Geurts, Evert G.M., "Analysis of Limit Cycle Oscillation/Transonic High Alpha Flow Visualization, Part 1: Discussion", AFRL-VA-WP-TR-1998-3003, 1998.

21 Cunningham, Jr., Atlee M., Geurts, Evert G.M., "Analysis of Limit Cycle Oscillation/Transonic High Alpha Flow Visualization, Part 2: Stationary Model Data", AFRL-VA-WP-TR-1998-3004, 1998.

22 Cunningham, Jr., Atlee M., Geurts, Evert G.M., "Analysis of Limit Cycle Oscillation/Transonic High Alpha Flow Visualization, Part 3: Oscillating Model Data", AFRL-VA-WP-TR-1998-3005, 1998.

Mach	0.225									
Reynolds	~ 3.8 *10^6		~ 8.0*10^6							
Frequency	5.7		5.7			7.6			11.4	15.2
Amplitude	0.5	0.5	0.5	4.0	8.0	2.0	4.0	8.0	2.0	2.0
Alpha		#								
4.0										
5.0										
6.0	7	36	107	135	147	158	172	185	199	213
7.0										
8.0	8	37	108							
9.0										
10.0	9	38	109	136	148	159	173	186	200	214
10.5										
11.0										
11.5										
12.0	10	39	110							
12.5										
13.0										
14.0	11	40	111	137	149	160	174	187	201	215
15.0										
16.0	12	41	112							
17.0	13	42	113							
18.0	14	43	114	138	150	161	175	188	202	216
19.0	15	44	116							
20.0	16	45	117							
21.0	17	46	118							
22.0	6 18	35 47	106 119	139	151	162	176	189	203	217
23.0	19	48	120							
24.0	20	49	121							
25.0										
26.0	21	50	122	134 140	145 152	157 163	171 177	184 190	198 204	212
27.0										
28.0	22	51	123							
29.0										
30.0	23	52	124	141	146 153	164		191	205	218
32.0	24 25	53	125				178			
34.0	26	54	126	142	154	165		192		219
36.0	27	55	127				179			
38.0	28	56	128	143	155	166		193	207	220
40.0	29	57	129							
42.0	30	58	130	144	156	167	180	194	208	221
44.0		59	131			168	181	195	209	
46.0		60	132			169	182	196	210	
48.0			133			170	183	197		

Table 1a: Simple Strake test programme, harmonic oscillations at Mach = 0.225

without fillerplate

Remark: The y=0 plane was located on a distance of 7 mm from the tunnel sidewall which corresponded to the local displacement thickness of the tunnel sidewall boundary layer. To impose the start of the vortex on the apex, a little flat plate, the filler plate was attached to the model.

Mach	0.600							
Reynolds	~ 8.0*10^6							
Frequency	5.7	7.6	11.4	15.2				
Amplitude	0.5	4.0	8.0	2.0	4.0	8.0	2.0	2.0
Alpha								
4.0	325							
5.0								
6.0	326	357	371	382	394	406	420	438
7.0								
8.0	327							
9.0								
10.0	328	358	372	383	395	407	421	439
10.5								
11.0	329							
11.5								
12.0	330							
12.5								
13.0	331							
14.0	332	359	373	384	396	408	422	440
15.0	333							
16.0	334							
17.0	335							
18.0	336	360	374	385	397	409	423	441
19.0	337							
20.0	338							
21.0	339							
22.0	340	361	375	386	398	410	424	442
23.0	341							
24.0	342	363	370	381	393	405	419	437
25.0	343							
26.0	324 344	356 364	376	387	399	411	425	443
27.0								
28.0	345							
29.0								
30.0	346	365	377	388	400	414	426	444
32.0	347					412		
34.0	348	366	378	389	401	415	427	445
36.0	349					413		
38.0	350	367	379	390	402	416	428	446
40.0	351							
42.0	352	368	380	391	403	417	429	447
44.0	353							
46.0	354	369		392	404	418	430	448
48.0	355							

Table 1b: Simple Strake test programme, harmonic oscillations at Mach = 0.6

Mach	0.900								
Reynolds	~ $8.0*10^6$								~$14.0*10^6$
Frequency	5.7			7.6			11.4	15.2	5.7
Amplitude	0.5	4.0	8.0	2.0	4.0	8.0	2.0	2.0	0.5
Alpha									
4.0	499								527
5.0	500								528
6.0	501	566	574	584	592	601	609	617	529
7.0	502								530
8.0	503								531
9.0	504								533
10.0	505	567	575	585	593	602	610	618	534
10.5									535
11.0	506								536
11.5									537
12.0	507								538
12.5									539
13.0	508								540
14.0	509	568	576	586	594 595	603	611	619	541
15.0	510								542
16.0	511								543
17.0	512								544
18.0	513	569	579	587	596	604	612	620	545
19.0	514								548
20.0	515								547
21.0	516								549
22.0	517	570	580	588	597	605	613	621	526 550
23.0	518								551
24.0	519	565	573	583	591	600	608	616	
25.0	520								553
26.0	521	571	581	589	598	606	614	622	554
27.0	522								555
28.0	523								556
29.0	524								557
30.0	525	572	582	590	599	607	615	623	558
32.0	559								
34.0	560								
36.0	561								
38.0	562								
40.0	563								
42.0	564								
44.0									
46.0									
48.0									

Table 1c: Simple Strake test programme, harmonic oscillations

Mach	0.225			0.600		0.900	
Reynolds	~ $3.8*10^6$	~ $8.0*10^6$		~ $8.0*10^6$		~ $8.0*10^6$	
Amplitude	8.0	8.0	16.0	8.0	16.0	8.0	16.0
Alpha							
6.0		235 236 237 238 239		454 455 456 457 458		625 639 640 641 642 643	
10.0		240 241 242 243 244					
14.0		245 246 247 248 249	296 297 298 299 300	459 460 461 462 463 464	485 486 487 488 489 490 491	644 645 646 647	662 663 664 665 666 667
18.0	62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77	250 251 252 253 254	301 302 303 304 305				
22.0		255 256 257 258 259	306 307 308 309 310	449 450 451 452 453	480 481 482 483 484	624 626 627 628 629 630 631 632 633 634 635 636 637 638	656 657 658 659 660 661
26.0	78 79 80 81 82 83 84 85 86 87 88	229 230 231 232 233 234 260 261 262 263 264 265	291 292 293 294 295				
30.0		266 267 268 269	311 312 313 314 315	465 466 467 468 469 470 471 472 473 474	492 493 494 495 496	648 649 650 651 652 653 654	
34.0	89 90 91 92 91 92 93 94 95	276 277 278 279 280	316 317 318 319 320				
38.0		281 282 283 284 285		475 476 477 478 479			
42.0		286 287 288 289 290					

Table 2: Simple Strake test programme, manoeuvres, $1/T = 3.8$ Hz, $\Delta t = [\ 1\ /\ (3.8 * 128)\ ]$

Unsteady Transonic Delta Program DPN = 151

test conditions			Simple Strake configuration
alpha = 22.109 deg	Q = 6.690 kPa		
Mach = .225	Ptot = 195.256 kPa		
Re*10^-6 = 7.982	Ttot = 291.828 K		
dalpha = 8.342 deg			
freq = 5.700 Hz			
k = .192			
harm = 1			

BALANCE LOADS		aerodynamic coefficients			aero	angular deflections [deg]		
position	comp.	Zero	Re 1	Im 1	inertia [%]	Zero	Re 1	Im 1
main	CN	1.09156	3.45587	1.20868	3883.88			
	Cm	.08135	.24823	-.06273	174.38	-.056	-.035	.003
	Cl	-.37659	-.78329	-.38618	957.42	-.063	-.008	-.009

ACCELERATIONS					vibration mode			
nr	x [mm]	y [mm]	Amplitude [m/s^2]	Phase angle rel. to LVDT [deg]	section	y/b [%]	heave at p.a [mm]	pitch [deg]
11	-425.6	-12.0	75.286	2.197				
12	-215.6	-12.0	35.066	3.471	1	2.878	1.790	7.946
13	167.4	-12.0	28.761	-178.363				
21	-138.6	-116.9	24.535	16.071				
22	-46.6	-116.9			2	28.034	1.208	8.353
23	121.4	-116.9	24.104	-167.130				
31	-74.6	-189.9	8.681	18.730				
32	-10.6	-189.9			3	45.540	2.749	7.223
33	141.4	-189.9	26.302	-168.691				
41	29.4	-304.9	3.384	-172.471				
42	89.4	-304.9	17.520	-178.576	4	73.118	.588	8.675
43	152.4	-304.9	27.168	-178.495				
51	85.0	-374.9	15.733	-166.775				
52	121.4	-374.9	22.863	-163.986	5	89.904	1.179	8.758
53	157.4	-374.9	29.896	-164.250				

Table 3: Example of data output format of harmonic measurements, page 1

Unsteady Transonic Delta Program DPN = 151

PRESSURES section 1 c = 300.65 mm y =-209.06 mm

nr. up	nr. low	x/c [%]	Cp 0	ReCp 1	ImCp 1
101		2.00	-1.572	.899	-.972
102		5.00	-1.621	1.512	-.885
103		10.00	-1.557	2.213	-1.058
104		15.00	-1.987	4.878	-1.166
105					
106		30.00	-1.117	-2.346	-1.420
107		40.00	-.878	-2.855	-1.111
108		50.00	-.775	-2.952	-.989
109		60.00	-.756	-3.090	-.913
110		70.00	-.723	-2.848	-.752
111		79.00	-.663	-2.535	-.393
112		82.50	-.615	-2.426	-.177
113		85.00	-.574	-2.331	-.009
114		90.00	-.521	-2.240	.280
115		95.00	-.463	-2.179	.472
	151	10.00	.619	.889	.180
	152	20.00	.509	1.010	.241
	153	40.00	.336	.883	.292
	154	60.00	.247	.592	.295
	155	80.00	.164	.158	.267

PRESSURES section 2 c = 246.21 mm y =-273.97 mm

nr. up	nr. low	x/c [%]	Cp 0	ReCp 1	ImCp 1
201		2.00	-.913	1.992	-.914
202		5.00	-.918	2.009	-1.005
203		10.00	-.929	2.178	-1.034
204		15.00	-.894	2.310	-.948
205		18.00	-.879	1.119	-1.667
206		30.00	-.843	2.697	-.942
207		40.00	-.799	2.012	-.827
208		50.00	-.773	.686	-.814
209		60.00	-.720	-.331	-.827
210		70.00	-.668	-.058	-.047
211		79.00	-.596	-1.451	-.699
212		82.50	-.606	-1.636	-.696
213		85.00	-.569	-1.674	-.637
214		90.00	-.556	-1.878	-.540
215		95.00	-.532	-2.116	-.389
	251	10.00	.601	.765	.217
	252	20.00	.495	.879	.259
	253	40.00	.330	.741	.280
	254	60.00	.224	.452	.273
	255	80.00	.101	-.012	.227

PRESSURES section 3 c = 194.13 mm y =-336.06 mm

nr. up	x/c [%]	Cp 0	ReCp 1	ImCp 1
301	2.00	-.523	1.506	-.653
302	5.00	-.528	1.477	-.653
303	10.00	-.522	1.463	-.702
304	15.00	-.513	1.353	-.698
305	18.00	-.506	.453	-1.029
306	30.00	-.513	.903	-.636
307	40.00	-.528	.339	-.536
308	50.00	-.560	-.051	-.440
309	60.00	-.537	-.248	-.390
310	70.00	-.538	-.468	-.466
311	79.00	-.554	-.692	-.594
312	90.00	-.549	-.931	-.676

PRESSURES section 4 c = 144.42 mm y =-395.32 mm

nr. up	x/c [%]	Cp 0	ReCp 1	ImCp 1
401	2.00	-.300	.666	-.550
402	5.00	-.308	.628	-.552
403	10.00	-.305	.525	-.516
404	15.00	-.315	.469	-.522
405	18.00	-.315	.416	-.523
406	30.00	-.324	.128	-.491
407	40.00	-.349	-.201	-.433
408	50.00	-.378	-.586	-.326
409	60.00	-.389	-.880	-.235
410	70.00	-.399	-1.025	-.221
411	79.00	-.396	-1.078	-.248
412	90.00	-.405	-1.155	-.280

Table 3 (continued): Example of data output format of harmonic measurements, page 2

Unsteady Transonic Delta Program DPN = 151

PRESSURES section 5 b = 82.70 mm x =-269.60 mm

nr. up	y/b [%]	Cp 0	ReCp 1	ImCp 1
501	6.62	-.440	-1.518	-.267
502	20.43	-.574	-2.557	-.119
503	34.05	-.835	-4.215	.156
504	47.67	-1.298	-5.928	.427
505	54.49	-1.541	-6.029	.374
506	61.29	-1.686	-5.240	.138
507	68.10	-1.645	-4.189	-.141
508	74.91	-1.419	-3.535	-.326
509	81.72	-1.124	-3.077	-.290
510	88.53	-1.123	-2.990	-.316

PRESSURES section 6 b = 233.73 mm x = -60.62 mm

nr. up	y/b [%]	Cp 0	ReCp 1	ImCp 1
601	38.90	-1.568	-3.997	-.031
602	42.93	-1.771	-4.141	-.364
603	46.93	-1.731	-4.658	-.575
604	50.99	-1.556	-5.500	-.593
605	59.03	-1.258	-5.123	-.664
606	67.07	-1.233	-6.098	-.728
607	71.11	-1.404	-6.762	-.944
608	75.56	-1.965	-4.665	-1.308
609	80.00	-2.647	4.103	-1.041
610	84.44	-1.874	3.100	-.957
102	89.45	-1.621	1.512	-.885

PRESSURES section 7 b = 417.90 mm x = 100.71 mm

nr. up	y/b [%]	Cp 0	ReCp 1	ImCp 1
701	22.71	-.036	.673	-.516
702	28.21	-.312	.592	-.066
703	33.72	-.778	-.192	.370
704	39.26	-.891	-2.468	.079
705	44.69	-.870	-3.140	-.631
109	50.03	-.756	-3.090	-.913
706	55.28	-.700	-2.560	-.945
707	60.46	-.752	-.957	-.960
208	65.56	-.773	.686	-.814
708	70.59	-.689	.802	-.668
709	75.54	-.613	.672	-.627
307	80.42	-.528	.339	-.536
710	85.22	-.443	.305	-.517
711	90.19	-.374	.340	-.513
405	94.60	-.315	.416	-.523

SECTION COEFFICIENTS

section	comp.	Zero	Re 1	Im 1
1	CN_u	.976	1.357	.770
	CN_l	.319	.627	.261
	CN_t	1.295	1.984	1.031
	Cm_u	-.120	-.803	-.061
	Cm_l	-.026	-.065	-.072
	Cm_t	-.146	-.868	-.133
2	CN_u	.733	-.508	.787
	CN_l	.295	.482	.250
	CN_t	1.029	-.026	1.037
	Cm_u	-.140	-.305	-.121
	Cm_l	-.017	-.024	-.062
	Cm_t	-.157	-.329	-.183
3	CN_u	.507	-.118	.604
	Cm_u	-.118	-.199	-.136
4	CN_u	.341	.412	.370
	Cm_u	-.087	-.290	-.060
5	CN_u	.992	3.683	.051
	Cl_u	-.553	-1.968	-.040
6	CN_u	1.531	3.071	.489
	Cl_u	-.745	-1.060	-.355
7	CN_u	.464	.271	.512
	Cl_u	-.266	-.140	-.282

Table 3 (continued): Example of data output format of harmonic measurements, page 3

alpha/306_1

6.791	6.868	7.028	7.161	7.300	7.507	7.704	7.892
8.164	8.474	8.782	9.160	9.575	9.953	10.364	10.836
11.294	11.771	12.318	12.863	13.412	14.042	14.694	15.319
15.996	16.714	17.401	18.110	18.866	19.595	20.323	21.109
21.891	22.647	23.432	24.203	24.925	25.665	26.421	27.135
27.847	28.577	29.264	29.920	30.578	31.178	31.721	32.274
32.804	33.274	33.747	34.217	34.620	34.989	35.351	35.662
35.942	36.237	36.500	36.715	36.931	37.115	37.224	37.299
37.345	37.329	37.284	37.225	37.112	36.966	36.810	36.597
36.321	36.018	35.667	35.254	34.828	34.381	33.890	33.397
32.906	32.368	31.806	31.246	30.636	29.979	29.324	28.648
27.931	27.217	26.495	25.739	24.985	24.234	23.443	22.645
21.864	21.068	20.279	19.534	18.778	17.993	17.246	16.526
15.784	15.071	14.407	13.743	13.098	12.506	11.926	11.359
10.851	10.366	9.874	9.428	9.029	8.645	8.305	8.022
7.751	7.502	7.300	7.114	6.948	6.831	6.737	6.655
6.615	6.585	6.535	6.514	6.522	6.505	6.482	6.485
6.469	6.447	6.468	6.500	6.502	6.506	6.507	6.477
6.455	6.462	6.460	6.462	6.489	6.502	6.496	6.507
6.511	6.485	6.470	6.469	6.462	6.473	6.501	6.512
6.516	6.522	6.506	6.486	6.490	6.487	6.475	6.497
6.530	6.538	6.557	6.587	6.581	6.564	6.576	6.584
6.588	6.619	6.648	6.649	6.659	6.674	6.662	6.647
6.651	6.659	6.673	6.701	6.718	6.723	6.730	6.724
6.710	6.711	6.710	6.702	6.722	6.751	6.752	6.757
6.772	6.755	6.730	6.736	6.739	6.728	6.745	6.773
6.775	6.778	6.786	6.768	6.745	6.744	6.737	6.733
6.756	6.776	6.778	6.783	6.779	6.754	6.741	6.743
6.736	6.740	6.764	6.773	6.772	6.781	6.772	6.746
6.740	6.742	6.733	6.743	6.767	6.773	6.774	6.777
6.760	6.738	6.736	6.732	6.728	6.748	6.764	6.762
6.768	6.772	6.746	6.725	6.723	6.714	6.719	6.750

Cp101/306_1

-0.858	-0.888	-0.828	-0.866	-1.186	-1.506	-1.485	-1.293
-1.247	-1.316	-1.350	-1.364	-1.392	-1.408	-1.433	-1.494
-1.564	-1.617	-1.654	-1.690	-1.746	-1.792	-1.775	-1.742
-1.767	-1.778	-1.699	-1.624	-1.637	-1.659	-1.639	-1.642
-1.690	-1.745	-1.800	-1.854	-1.889	-1.926	-1.948	-1.891
-1.799	-1.773	-1.762	-1.681	-1.597	-1.546	-1.442	-1.308
-1.243	-1.181	-1.045	-0.948	-0.950	-0.950	-0.974	-1.145
-1.343	-1.365	-1.262	-1.203	-1.214	-1.208	-1.104	-0.953
-0.943	-1.092	-1.150	-1.072	-1.071	-1.085	-0.910	-0.770
-0.911	-1.035	-0.906	-0.806	-0.869	-0.889	-0.929	-1.128
-1.219	-1.043	-0.923	-0.983	-0.974	-0.903	-0.963	-1.069
-1.121	-1.207	-1.247	-1.099	-0.952	-1.001	-1.098	-1.135
-1.217	-1.339	-1.390	-1.402	-1.430	-1.449	-1.479	-1.540
-1.574	-1.576	-1.594	-1.593	-1.544	-1.514	-1.519	-1.495
-1.434	-1.367	-1.305	-1.262	-1.227	-1.175	-1.149	-1.155
-1.109	-1.061	-1.157	-1.260	-1.124	-0.878	-0.815	-0.876
-0.869	-0.840	-0.863	-0.869	-0.848	-0.857	-0.868	-0.853
-0.854	-0.866	-0.857	-0.852	-0.863	-0.860	-0.852	-0.860
-0.862	-0.854	-0.858	-0.863	-0.856	-0.856	-0.862	-0.858
-0.855	-0.861	-0.860	-0.855	-0.860	-0.861	-0.856	-0.858
-0.862	-0.857	-0.857	-0.862	-0.859	-0.856	-0.861	-0.860
-0.856	-0.860	-0.861	-0.857	-0.859	-0.861	-0.858	-0.857
-0.861	-0.859	-0.857	-0.860	-0.860	-0.857	-0.859	-0.860
-0.857	-0.859	-0.861	-0.858	-0.858	-0.861	-0.859	-0.857
-0.860	-0.859	-0.857	-0.859	-0.860	-0.857	-0.859	-0.860
-0.858	-0.858	-0.860	-0.859	-0.858	-0.860	-0.859	-0.857
-0.859	-0.860	-0.858	-0.859	-0.860	-0.858	-0.858	-0.860
-0.859	-0.858	-0.860	-0.859	-0.858	-0.860	-0.860	-0.858
-0.859	-0.860	-0.858	-0.858	-0.860	-0.859	-0.858	-0.860
-0.859	-0.858	-0.860	-0.860	-0.858	-0.859	-0.860	-0.858
-0.859	-0.860	-0.859	-0.858	-0.860	-0.859	-0.858	-0.860
-0.860	-0.858	-0.859	-0.860	-0.859	-0.859	-0.860	-0.859

Table 4: Example of data output format of manoeuvre measurements; $\Delta t = [\ 1 / (3.8 * 128)\ ]$

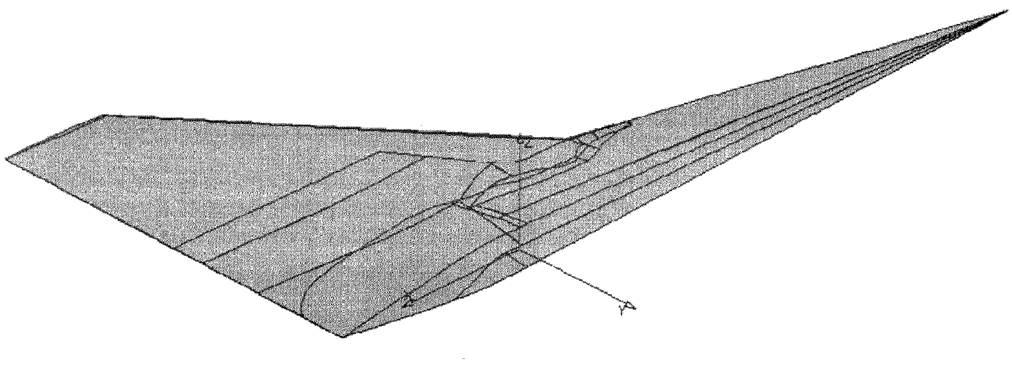

Figure 1: CATIA example of NLR Transonic Simple Straked Delta Wing

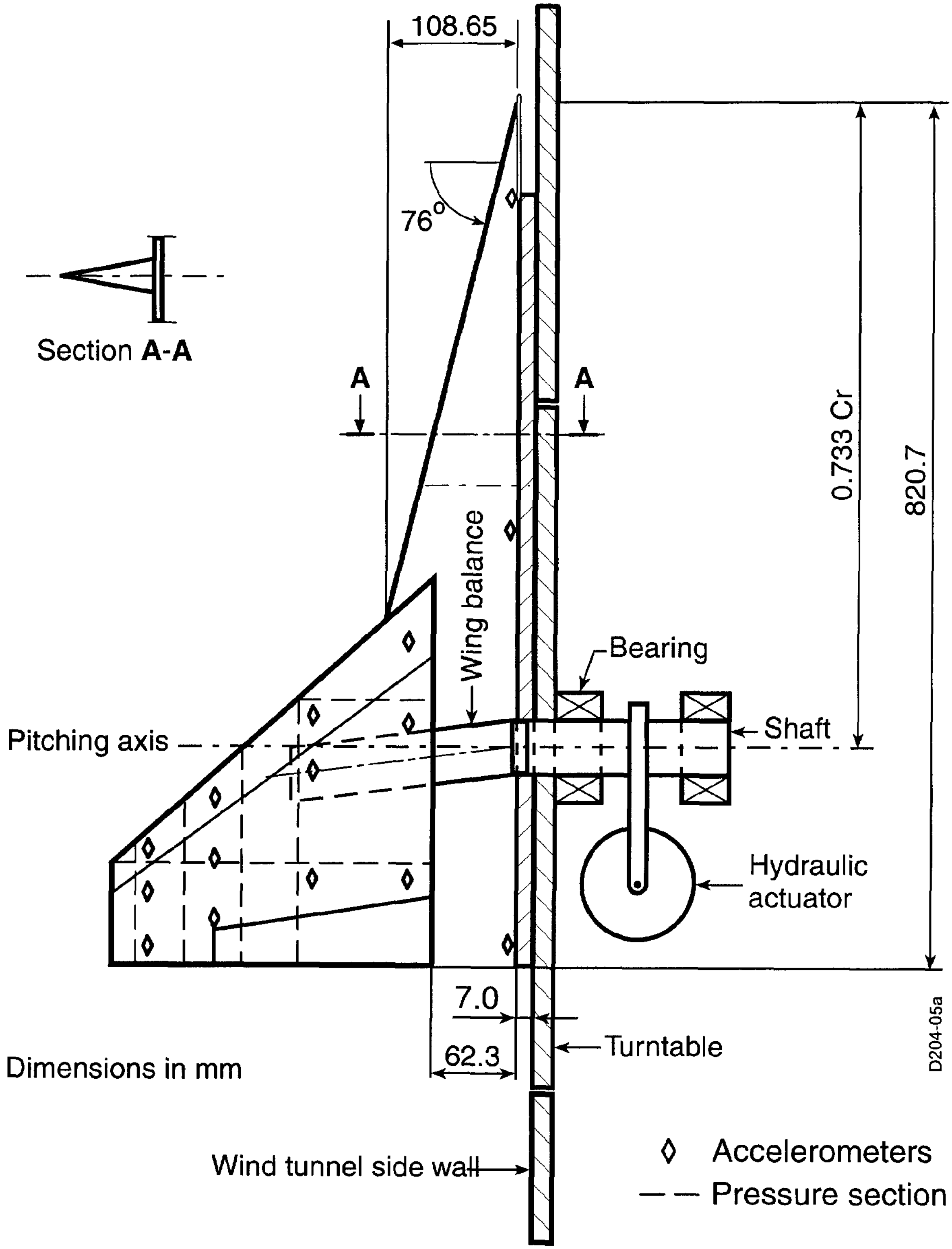

Figure 2: NLR Transonic Simple Straked Delta Wing configuration (dimensions in mm)